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COMMUNICATION SATELLITES

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The communication satellite although not new in concept received primary impetus with the launchings of the Project Score, Echo and Courier experiments. Their success was not only in the specific accomplishment of mission but in the foretelling of the future and opening up via satellites the panorama of global communications to the communications industry and the public.

The use of satellites for application purposes is an engineering development which must be preceded by the development of adequate launch vehicles, suitable stabilization and orientation techniques, and extensive knowledge of the nature of the space environment. It appears; however, that within the existing constraints on bandwidth, ground installations, limited mutual visability times, limited duty cycles, and short satellite lifetimes, a communications satellite program both passive and active can be effectively prosecuted to the point where the justification of such satellites for global communications is more readily assessable. Such a program falls well within the scope of the NASA mission, that of advancing both research and technology in the uses of space.

The need for communication satellites is based on many premises:

1. Existing facilities such as land lines and submarine cables in the next decade will be overextended.

2. Wide bandwidth information cannot be directly transmitted over vast distances utilizing the high frequency spectrum.

3. Many areas of the world require point to point communications over regions where rugged terrain makes the establishment of land line repeaters prohibitive.

4. Emergency wideband communication to specific remote sites is perhaps best accomplished via satellite.

5. Public service broadcasting to large sparsely developed areas will probably be contingent on the achievement of high powered satellite transmitting equipment.

There are two types of communication satellites under present experimental investigation; one designed to operate as a single or series of reflectors and hence called the passive repeater, the other designed to receive the transmitted signal, amplify it, and retransmit it, hence called the active repeater. Although much has been written regarding them, it may be of value to review the salient features of each.

Type	Advantages	Disadvantages
Passive	1. Simplicity	1. Larger transmitter power required for same bandwidth
	2. Wide frequency range	2. Large antenna installations & ultra-sensitive receiving equipment necessary
	3. Multiple access without interference	3. Mutual visability times limited by greater weight, hence, lower orbital altitude for a given booster.
	4. Mainly mechanical technology.	4. Different transmit/receive frequencies for any two stations.
	5. Visual as well as radio tracking.	
Active	1. Reasonable ground to satellite transmitting powers.	1. Less reliability
	2. Achievable satellite to ground transmitting powers for low orbit wideband communications or high orbit narrow band communication.	2. More costly
	3. Identical frequencies may be used.	

It is interesting to note that the passive repeater which has surface orientation and reflectivity gain begins to approach the spin stabilized omnidirectional radiating active satellite from considerations of power and bandwidth. The active satellite cannot also remain unoriented. If it is in truth to economically perform its mission, high gain directive antennas will be required, as orbital altitude is increased to enhance mutual visibility or communicating times.

The current NASA communication satellite program comprises a two-fold approach, pursuing jointly research and technological developments in both the passive and active repeater area.[1]

The passive satellite research program consists of:

1. The development of rigidized sphere techniques.

2. The engineering of balloon container separation and proper balloon inflation.

3. The development of deployment techniques for equalized orbital spacing of passive satellites.

The passive satellite flight programs are:

1. Ballistic launches of 135 ft. diameter rigidized spheres with television and recoverable camera coverage of container separation and initial balloon inflation. (AVT launches).

2. A low altitude orbital launch to test lifetime, rough sphericity, and effect of radiation pressure on the orbit. (Project Echo A-12)

3. An experiment to deploy three passive structures equally spaced in orbit to fully study lifetime, deployment techniques, and communications utility at the 1500-1700 mile altitude. (Project Rebound)

The existing active repeater communication satellite projects which the NASA is pursuing or sponsoring are:

1. Project Relay - A low altitude orbit 1000 - 3000 miles spin stabilized. Two redundant transponders each providing one-way TV and two-way telephony capability. Ground transmitter 10 kw, frequency centered at 1725 mc, satellite frequency 4170 mc. Satellite output power 10 watts with system

configured for use of 85 foot 150^{o}k noise temperature self-tracking antennas. Satellite contractor RCA, Ground Stations AT&T, IT&T, Brazil, France, Germany and Great Britain.

2. Project TSX - In cooperation with AT&T, similar orbit, spin stabilized, ground transmitter 2 kw, frequency centered at 6390 mc. Satellite frequency 4170 mc with an output of about 3 watts with system configured for 30 - 50^{o}k noise temperature, self-tracking antennas and use of masers and/or FM feedback receivers. One way TV and two-way telephony capability in a single transponder. Satellite contractor BTL, ground stations same as Project Relay.

3. Project Syncom - Narrow band transponder in a 33^{o} equatorial orbit. Ground transmitter frequency in the 8000 mc band. Satellite output power about 2 watts in the 2000 mc band. Spin stabilized with simple gas jet period and attitude control. Satellite contractor Hughes Aircraft Company, special ground stations provided by the U. S. Army ADVENT Management Agency.

The present active repeater satellite configurations employ fm-fm modulation concepts. Perhaps other forms of information encoding will follow as the field progresses. Ground transmission frequencies vary from 1700 mc to 8000 mc with satellite to ground frequencies of 2000 mc to 4000 mc being planned initially. The quest for large chunks of the frequency spectrum is pushing the communication satellite to bands more commonly used for radar. Difficulty due to rain and atmospheric effects will perhaps place some restraint on this upward trend. The transponders themselves translate the incoming signal after amplification to a new frequency. There is no demodulation in the satellite equipment. Some transponders translate lineally, others multiply the deviation, with output bandwidths ranging from 25 to 50 mc. Large self-tracking antennas such as 85 foot dishes or 60 foot horns are required and reduction of ground system noise temperatures by use of cooled parametric amplifiers or masers is in some cases necessary. The widespread investigation of the use of fm-feedback receivers with an anticipated 5 to 7db improvement in noise threshold depression appears likely. Programming of the ground radiated power will be required in some of these systems for two-way operation and multiple access from a variety of ground transmitters to the satellite is not possible in present active repeater configurations.

For the active communication satellite to become an effective link in the global network, many problems not unknown to rocket and rocket subsystem groups will have to be resolved. Preliminary desires are for satisfactory operating lifetimes of three to five years in orbit with ultimate lifetimes up to ten years. This then predicates, as a requirement, knowledge of the space environment, of behavior of materials and components in space, and levels of reliability an order of magnitude greater than we presently know or have achieved. One of the most significant areas that we face is the development of a simple long lifetime earth orientation system that will permit the use of a high gain directive satellite antenna. Its value in terms of r.f. system parameters represents a factor of 7-10 improvement in power or receiver gain and perhaps 15 inch bandwidth improvement. If a simple orientation cannot be provided, and if electrically steerable antennas are too costly in weight, then the complexity and cost imposed will be severe.

If the law of supply and demand holds true the initial global communication traffic will follow the population density patterns with perhaps primary service being of the point to point type. Traffic from the United States to Europe will be routed via existing land lines to an East Coast terminal point where a complex of large tracking antennas will radiate to and receive from the satellite over water spans which are uneconomic to bridge by additional submarine cables. Traffic to the Far East and Australia would logically proceed by land line to the West Coast and, thence, by submarine cable to Hawaii where a similar satellite terminal complex would be installed. The United States would be similarly linked to specific population centers in South America. Where submarine cable runs are too tenuous or too long to maintain, double satellite hops can be envisaged. If economic factors outweigh national pride, true global communications will not be the sole province of any one country but will be accomplished by cooperative sharing of both satellites and ground terminals by many nations.

The desire for early global communications via satellite at present surpasses our demonstrated capability of constructing a group of complex satellites which can perform their functions for ten years and provide mutual communication for periods of time which would be both economic and for other considerations of value. Moreover, our knowledge of the behavior of materials in the environment of space is limited. None of our present complex satellites has operated completely without some degradation for over one year. Our methods of quality control while sufficient for present day satellites would appear inadequate for the future. Our testing programs are involved and detailed but we have yet to simulate completely the space environment with solar radiation on the ground. Reliable techniques of long term stabilization, attitude orientation and orbital period control are still in the laboratory stage.

It would appear then that there is needed a combined program of government and industry directed towards the gathering of further space information, the expansion of materials testing for use in space, the pursuit of control of lifetime through quality, which may well have to start with the selection of the raw material itself, and the orbital flight testing of the systems which proceed directly towards our ultimate goals. Such ventures as we undertake should be viewed from considerations of economic investment, reliability, ease of maintenance, complexity of ground equipment, complexity of orbit prediction and tracking, and launch vehicle capability.[2]

With these points in mind, early consideration should be given to the investigation of the six hour sub-synchronous orbit either circular or elliptical at inclinations of 60° or 63.4°. It is within our present capability to attain such orbits using the Atlas-Agena B vehicle and carry sufficient weight to provide four wideband transponders suitable for either TV or multiplex telephony. Interim service to the major centers of communication could be furnished by a system of this type assuming adequate power, a simple orientation and period control device and addition of antenna gain capability.

Beyond this, using the Atlas-Agena B with a solid upper stage it is possible to carry a payload which would be experimentally significant to the 24 hour equatorial orbit, for it could allow for perhaps two wideband transponders with a simple period and orientation control. Concurrent with these two types of orbital approaches, there should be included flight tests primarily concentrating on environment and materials research as well as techniques of orientation, period control, reliability and long-term operation.

The ultimate achievement of the global communication system which solves all needs may be a series of passive satellite structures with gain which provide both multiple access and point to point communication in combination with an active 24 hour synchronous equatorial system which is nuclear powered to provide long term station keeping operation with radiated power sufficient to reach any part of the globe which has modest ground station or receiving equipment.

It should be emphasized that the need and desire for global communications is not solely the province of any one nation, that very concrete and sophisticated problems face us, that effective economic systems require both international cooperation and the combined talents of industry and government in many countries. Despite the problems we face there is encouragement in the fact that since the first demonstration of the concepts of the communication satellite less that two years ago, this one field has captured the imagination, the cooperation, and the economic support of many nations towards one goal, the improvement of man's ability to converse with his fellow man.

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